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14. ABSTRACT

This grant supported a variety of studies in the area of littoral processes typically as revealed by the optical remote sensing data of the Argus Program. One principle theme was the development of algorithms for estimating relevant geophysical variables such as longshore currents and wave directional spectra from ground-based optical cameras. The second theme was the study of observed nearshore physics. Much of the latter work focused on the morpho-dynamics of nearshore sand bars or foreshore morphological features. Like many nearshore phenomena, the dynamics of nearshore sand bars is dominated by strong feedbacks, with bars both causing and being caused by wave breaking. Weaknesses in our ability to characterize and understand such feedback systems are the single largest limitation in our current predictive capabilities.

Details of progress and publications were reported each year in the ONR annual reports and with the exception of the report from the final year, are not duplicated here.

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littoral processes, optical remote sensing, nearshore dynamics

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Optical Imaging of the Nearshore

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LONG-TERM GOAL

The long-term goal of nearshore processes research has been to develop a predictive understanding of the fluid dynamics of a random wave field shoaling over the complicated bathymetry of a natural beach, and the response of the beach to those overlying wave and current motions. Success requires advances in our understanding of nearshore physics, improvement in our capabilities for numerical modeling, and development and testing of methods for the rapid collection of the data required for model initial and boundary conditions and for data assimilation.

OBJECTIVES

Our program continues to follow three primary themes: a) studies of nearshore fluid dynamics, b) studies of the morphodynamic variability of the nearshore fluid-sediment system at longer time scales, and c) development of new or better data collection methods and methods to integrate these remotely sensed data with numerical models. Our program is strong in all phases, but somewhat unique in our focus on remote sensing methods for data collection in the nearshore. It is increasingly apparent that our future predictive capability is more limited by the availability of input data (the data starvation problem) than by weaknesses in our understanding of the physics or in our modeling know-how.

APPROACH

The primary sampling method used by the Coastal Imaging Lab has been optical remote sensing from land-based camera systems called Argus Stations. Developed in the Coastal Imaging Lab over several decades to serve a variety of research needs, the Argus Program has become a standard tool for nearshore research and coastal zone management. This year saw the culmination of this transition to global acceptance with the publication of a special issue of Coastal Engineering describing the results of CoastView, a three-year European Union program specifically addressing the application of Argus research-based methods to Coastal Zone Management problems in four countries, England, The Netherlands, Italy and Spain [*Davidson, et al.*, 2007]. The resulting volume included papers on the history and capabilities of Argus [*Holman and*

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Stanley, 2007], on the physics of daily to monthly coastal evolution [*Smit, et al.*, 2007], and on the application of Argus to a variety of Coastal Zone Management problems [*Kroon, et al.*, 2007]. Argus algorithms and methods also have potential applicability to overhead sampling from piloted and, interestingly, unmanned aircraft. With the recent proliferation of small UAVs for intelligence collection in defense-related applications, it is natural to determine the potential obstacles to the use of sophisticated quantitative applications from these platforms. Work with NATO colleagues using the Raven, a standard operational platform, found the imagery was of good quality but that navigation sensors were better suited to system flight control than imagery analysis, forcing the use of co-registration to a ground map such as a satellite image for adequate geometric control [*Pennucci, et al.*, 2007].

WORK COMPLETED

In his recently completed PhD thesis work, Chris Chickadel describes several important developments in Argus-based optical remote sampling. A 14-month study of the applicability of 1DH models on natural beaches was completed, finding that 71% of 218 runs were objectively classified as being alongshore variable, a result that conflicted with several previous studies based on in-situ array data (and thereby complicating the review process). This problem bears strongly on the future of Navy prediction systems as well as those of civilian observing systems since 2DH models are more complicated to implement and have substantially greater input data needs than their 1DH counterparts.

An optical method for estimation of wave directional spectral shape has been developed and tested using NCEX data. This method was then applied to estimation of refraction maps for waves over the entire NCEX area (e.g. Figure 1). Dense maps of peak wave direction in each of a suite of frequency bands are very useful for understanding the role of complex offshore bathymetry like the local submarine canyons to wave propagation and to nearshore circulation patterns forced by detailed refractive processes.

Over the past year we have focused on potential applications of optical polarimetry for making innovative nearshore measurements. Polarimetric imagery is more complex than traditional electro-optical sensing, since it involves arithmetic combinations of three separate images, each of which must be accurately co-registered and calibrated. We have now worked out error sensitivities and optimal filter orientations and are in the process of improving our camera gain models and calibration processes to a level required for extraction of accurate degree and azimuth of polarization measurements. Analysis methods are being developed for mapping the full two-dimensional surface wave field and the foreshore slope. Initial tests also show that polarization can be a good proxy for water content of sands and muds.

We continue to work on the problem of nearshore morphodynamics, the processes of pattern formation involving nonlinear coupling between bathymetry and overlying fluid motions. These processes drive bathymetric variability at a wide range of scales and generally can be characterized as nonlinear dynamic systems, with behavior we are only beginning to learn to describe. A recent joint paper with Plant [*Plant, et al.*, 2006]

modeled the complex behavior of nearshore sand bars in terms of two coupled partial differential equations whose coupled interactions can be analyzed in terms of an eigenvector decomposition of the coupling coefficient matrix. We are now extending the short sample record from that paper to longer time series and multiple beaches. A second paper has now been published describing of wave orbital ripples, also the result of fluid-bathymetry interactions, but on a much smaller scale [*Becker, et al.*, 2007].

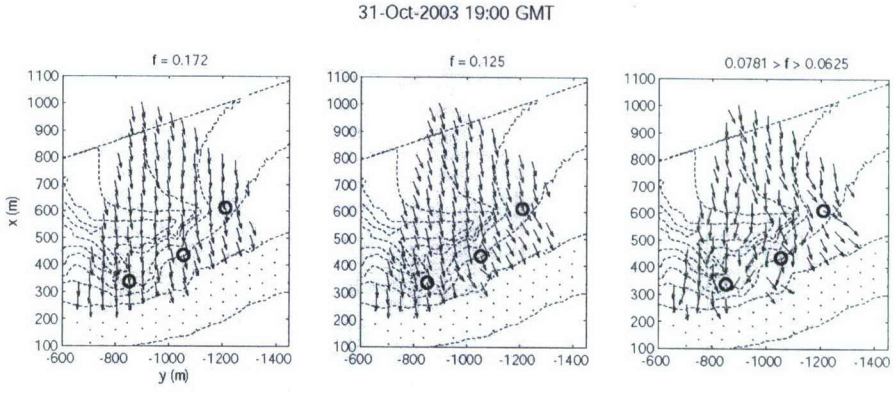

Figure 1. Peak wave direction maps from the NCEX experiment for three frequency bands, f = {0.172, 0.125 and a band average result from 0.078-0.062 Hz}. Lower frequency are more strongly affected by the canyon bathymetry so will be more important in driving nearshore patterns of circulation. Circles indicate in-situ instrument locations. Optical measurements clearly supplement the in-situ sampling density.

IMPACT/APPLICATION

Argus has an ever-widening impact on the world's community of nearshore researchers. Beyond the many publications listed here (directly linked to CIL efforts), there are many research efforts not reported that arise from the approximately 25 non-CIL Argus stations. The most recent Argus user group meeting in the summer of 2007 was attended by 40 scientists, including 27 visitors.

Optical remote sensing is an obvious solution to the large data needs to nearshore observing systems.

TRANSITIONS

Argus technology or spin-offs have been at the heart of many current Navy research efforts into practical optical remote sensing. This has included the VISSER program by

Dr. Todd Holland at NRL-SSC and connections through previous LRS efforts and follow-ons. Recently this work has expanded to explore the applicability of Argus methods to moving platforms such as small UAVs. This work is collaborative with NRL-SSC as well as the NATO Forward Eyes program run by Dan Conley. We continue collaboration with the U.S. Army Corps of Engineers both through Bill Curtis at Vicksburg and through the FRF on a variety of Argus issues and with the USGS in both research and applications-based work. Argus was the focus of the recently completed CoastView European Union program featuring the integration of Argus into standard Coastal Zone Management practice. Argus has been transitioned to commercial availability through transition agreements between OSU and Northwest Research Associates (for North America) and Delft Hydraulics (for the rest of the world).

RELATED PROJECTS

1 - Joint work with Dr. Todd Holland, NRL-SSC
2 – Collaboration with the WSC at Navoceano on nearshore remote sensing
3 – LRS follow-on efforts, particularly UAV development
4 – EU CoastView Program (2002 – 2005)
5 – Numerous collaborations with the Field Research Facility
6 – Three month sabbatical at the NATO research center in La Spezia (09-12/06)

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PATENTS

None

HONORS/AWARDS/PRIZES

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